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## Contributed paper

# FERMI@ELETTRA bunch compressor chicane mechanical design

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The FERMI@ELETTRA Free-Electron-Laser (FEL) project at the ELETTRA Laboratory of Sincrotrone Trieste, currently under construction and commissioning, will comprise a linear accelerator and two FEL beamlines. Two identical magnetic chicanes for bunch length compression will be installed in the linear accelerator (LINAC) tunnel. The first bunch compressor, at 300 MeV, has been recently installed and commissioned while the production and installation plan of the second one (at 600 MeV) is being defined. The chicane mechanical design has been achieved in collaboration with the supplier, Rial Vacuum srl. In this paper, the chicane mechanical design and the movable vacuum chambers are presented.

## 1. Introduction

The FERMI machine consists of three main sections: the linear accelerator, the undulator hall and the experimental area. The accelerator, schematically shown in figure 1, comprises the gun, the laser heater, four accelerating sections groups (L1–L4), two bunch compressors (BC1 and BC2) and the spreader (Various Authors, 2007).

The linear accelerator, except for the X-bend section and the BC2, is already installed and now under conditioning and commissioning.

The BC1 purpose is to reduce the electron bunch length, thus increasing the peak current, taking advantage of the beam correlated energy spread. Due to the accelerating process, there is an inherent longitudinal energy spread in the electron bunch. The tail energy ratio ( $\Delta E/E$ ) is higher than the head one. Passing through four bending magnets chicane, the path length is energy dependent and the electron bunch is compressed. At each bend, the electron bunch head delays with respect to the tail.

Mounting high homogeneity magnetic field dipoles and having diagnostic devices centred on the beam at each chicane position are the main advantages of the movable chicane.

The nominal BC1 energy is in the range of 230–300 MeV.

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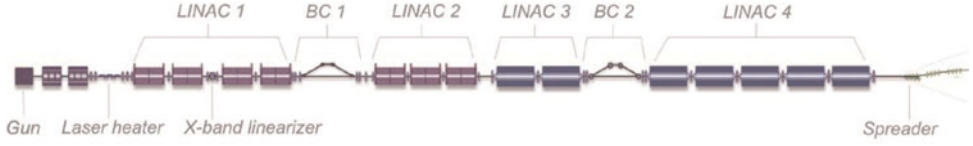


FIGURE 1. Schematic view of the FERMI linear accelerator.

## 2. Overview and mechanical requirements

BC1 consists of four chicane dipoles (B1–B4) and two fine tuning quadrupoles (Q1–Q2). The two central dipoles are mounted on a central stage that can have up to 365.61 mm motion orthogonal to the beam axis. A stepper motor provides movement to the central stage and a linear encoder controls its exact position. The position accuracy of dipoles is within 50  $\mu\text{m}$ . The chicane is symmetric (B1–B2 distance is equal to B3–B4 distance). Q1 (Q2) is placed between B1 (B3) and B2 (B4). The quadrupole magnets rotate and remain at a fixed distance (600 mm) from the pivot points (B1 and B4). For all dipole positions, the quadrupole magnets stay centred on B1–B2 and B3–B4 segments. A beam-position-monitor (BPM), a two-blade scraper (SCPR) and a multi-screen (MSCR) equipped with optical-transition-radiation (OTR) and yttrium–aluminum–garnet (YAG) targets are placed between the central dipoles. The position of such diagnostic devices remains fixed with respect to the central dipoles. The maximum chicane angle is  $7^\circ$  and the corresponding dipole magnetic field at 250 MeV is 0.1173 T. Movable vacuum chambers approximate the beam trajectory as much as possible. Figure 2 shows the BC1 layout and its overall dimensions.

## 3. Mechanical design

The BC1 mechanical structure consists of three carbon-steel tables with 30 mm thick aluminium top plates. The central table top plate houses two linear rails, each with two roller bearing carts, on which an aluminium sliding main plate is mounted. The main plate supports the two central dipoles and an adjustable aluminium plate. Such plate carries the SCPR and the MSCR, previously aligned, and the BPM, mounted on support independently adjustable.

B1 and B4 are mounted on the first and third fixed tables. Two rotating platforms supporting Q1 and Q2 are guided by a circular rail and borne by two adjustable ball

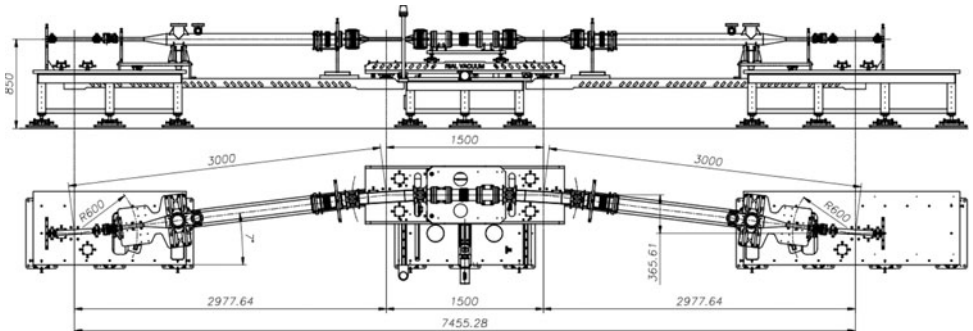


FIGURE 2. Bunch compressor layout, the diagnostic devices and magnets are not shown.

transfer units. Each platform is driven by a rigidly connected aluminium beam pivoting on the fixed table and connected to the movable platform by a sliding constraint. The aluminium beam design is aimed at minimizing deformations, guarantee of system position accuracy and reproducibility, keeping under control the total mass and the overall dimensions. The beam pivots are accurately located under each dipole centre, and therefore all devices (quadrupoles and vacuum chambers) that are rigidly connected to the beams stay aligned with the dipoles geometrical centres. All pivots consist of two rotating bearings and one thrust bearing. The B2 and B3 pivots also have a sliding guide in order to compensate for the B1–B2 (B3–B4) distance change.

#### 4. Vacuum chambers

The chicane vacuum chambers are symmetric (see figure 3) and are allowed only one movement, either rotation or longitudinal motion. The vacuum bellows movements are decoupled, being exclusively either a rotation or an elongation allowed. The dipole gap and the quadrupole bore diameter is 32 mm. The vacuum chambers variable aperture is the best compromise among magnets aperture, beam-to-chamber-wall distance, beam shape and vacuum load resistance.

Each BC1 portion consists of four vacuum chambers: B1 chamber (VC1), B1–B2 vacuum chamber (VC2), elongation compensator (VC3) and B2 chamber (VC4). VC1 and VC4, across the B1 and B2 dipoles, respectively, are made of oxygen-free copper. The VC1 cross-section is elliptical, 3 mm thick and measures  $25 \times 38 \text{ mm}^2$

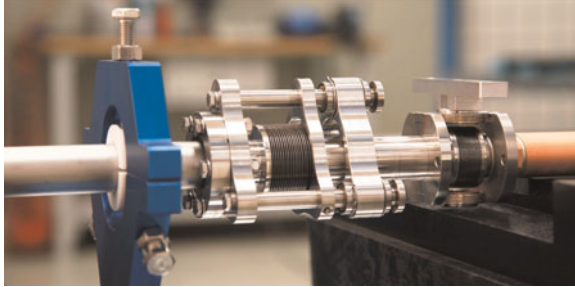


FIGURE 3. VC1 vacuum chamber.

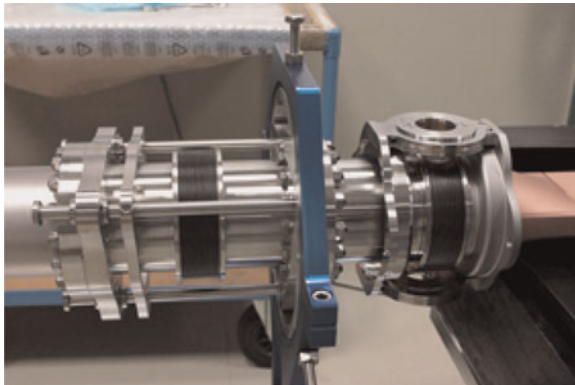


FIGURE 4. VC3 and VC4.

internally. VC4 has a racetrack 4 mm thick cross-section and is  $22 \times 98 \text{ mm}^2$  internally. VC1- and VC4-type chambers are brazed, to accommodate either the copper-to-copper shape variations or the copper-to-stainless steel (SS) bellows transitions.. Copper parts have been wire EDM'ed (electrical-discharge-machining). The low gap to circular shape transition is brazed as well. Hinge components are tungsten-inert-gas (TIG) welded to the previous described assembly. VC2 is a circular SS chamber with different diameters in order to fit both the quadrupole bore radius and the beam shape increase. VC3 compensates the distance variation during the motion. Figures 3 and 4 show movable vacuum chamber details.

## 5. Conclusion

The FERMI@ELETTRA bunch compressor and its movable vacuum system have been briefly presented. The system has been successfully assembled and tested. The leak check has shown overall helium leaks lower than  $1 \times 10^{-10} \text{ mbar l s}^{-1}$ . The vacuum chamber hinge's position at different chicane angles has been checked as well and the variation from the theoretical prediction is within 0.50 mm. The upcoming FERMI commissioning phase will provide information on the BC1 operating performance.

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